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SIMULATION, GAMING AND TRAINING IN A COMPETITIVE MULTIMODAL MULTICOMPANY INTERCITY PASSENGER TRANSPORTATION ENVIRONMENT

by

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ABSTRACT

This paper presents a micro-computerized simulation game designed as an analysis, experimentation and training tool in the field of intercity passenger transportation planning and management. The simulation deals with different transportation modes and companies in a competitive environment, whether it be regulated or not. The background, philosophy and objectives of the game are discussed in relation to the intrinsic complexity of decision making and the state of development of modelling in transportation.

Key words : simulation, gaming, training, experimentation, companies, competition, intercity passenger transportation, planning, management.

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RÉSUMÉ

Cet article présente un simulateur d'entreprises de transport interurbain de passagers. Conçu sous la forme d'un jeu de simulation sur micro-ordinateur, il est destiné à servir d'instrument d'analyse, d'expérimentation et de formation dans le domaine de la planification et de la gestion du transport interurbain de passagers. La simulation implique différents modes et différentes compagnies de transport en concurrence les unes avec les autres dans un environnement réglementé ou déréglementé. Le cadre, la philosophie et les objectifs du simulateur sont discutés en relation avec la complexité intrinsèque de la prise de décision en transport ainsi qu'en relation avec l'état des techniques de modélisation en ce domaine.

Mots-clés : jeu, simulation, formation, expérimentation, entreprises, concurrence, transport interurbain de passagers, planification, gestion.

1. INTRODUCTION

Planning and management in the intercity passenger transportation industry is a highly complex task that is considered by some people to require more awareness of the social, economic and political environment rather than scientific and rational capabilities. Whatever deserves the greater weight, one question that remains to be answered is how to train individuals in order to help them understand – in a comprehensive and systemic way – all the dimensions of the transportation environment in which they are involved and make good decisions in complex situations.

This question is not limited to the transportation industry. Actually, it is at the core of a more general debate that concerns education and training in business and management (for example, see Eilon [5]). In transportation, however, this problem is aggravated by the difficulty to comprehend and model the behavior of both the supply and demand sides of transportation systems, including their interaction on spatial networks.

Experimentation is also a crucial issue for any intercity passenger transportation company. As in many other fields, there is a need for ways of experimenting alternative policies or opertating strategies without being forced to test them in the "real world".

In this paper, we present a contribution to the technolgoy of simulation gaming as a means to model complexity in transportation analysis, education and training. The objective is to present a micro-computerized simulation game designed as an analysis, experimentation and training tool in the field of intercity passenger transportation planning and management. The simulation deals with different transportation modes and companies in a competitive environment, whether it be regulated or not. The paper is as much concerned with a discussion of the background, philosophy and objectives of the game in relation to transportation modelling, as it is with the presentation of the game itself.

2. SCHEMATIC PROBLEM SETTING

The difficulty of planning and management in a public or private intercity passenger transportation company results from the complexity of both the decision-making process and its environment. These "internal" and "external" complexities are depicted in Figure 1.

2.1 The Spatial Network Environment

A transportation company does not operate in a vacuum. Unlike most companies in other industrial sectors (except for their transportation component, where applicable), it is mainly concerned with a spatial network. This network dimension constitutes a huge difference when compared with other industries since the understanding of what is supply and what is demand and how they equilibrate on the network is theoretically difficult to clarify and model.

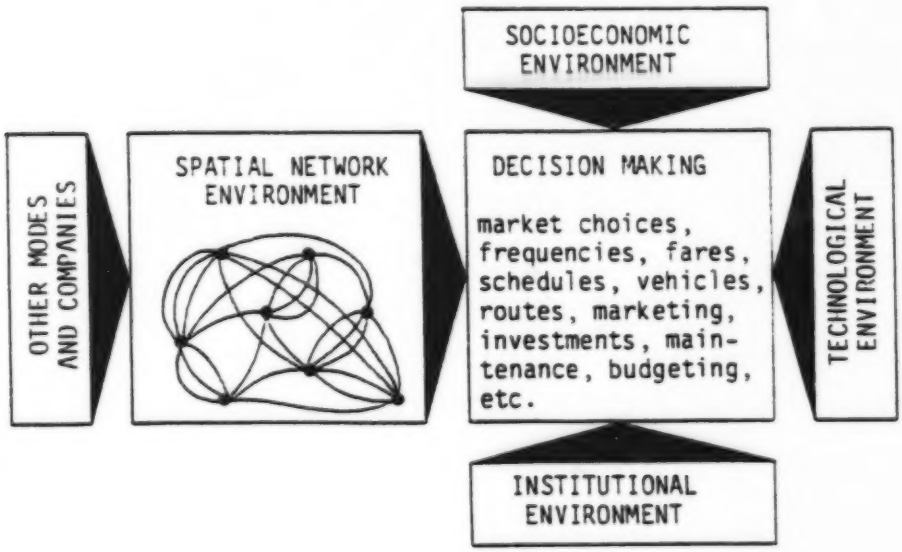

Figure 1. The internal and external complexity of decision making

Prices and other transportation service attributes such as frequencies, travel times, schedules, vehicle comfort and congestion effects (e.g. not finding a place on a train or waiting too long at an airport) are many characteristics of the supply that are difficult to weigh or aggregate. Furthermore, some of these characteristics cannot be measured a priori. For instance, the degree of congestion depends on the transportation demand which in turn depends on congestion levels. In other words, some of the non-price attributes of the supply depend on both the supplier's decisions and the consumer's responses; as a matter of fact, service levels (trip time, waiting time, probability to find a seat, etc.) may deteriorate as the actual demand increases. Moreover, when different companies are competing in the same market, the service levels corresponding to each company may be influenced by the supplied services and market shares of the other companies. The supply-demand equilibrium in transportation results from a dynamic multidimensional spatial process whose outcome (for fixed prices) includes the service levels experienced by travellers and the volumes actually moving through the system. For a detailed discussion of these conceptual matters, see among others, Manheim [17], Morlok [19], Florian and Gaudry [8] and Florian, Gaudry and Lardinois [9].

Therefore, one of the main problems confronting education and training in transportation is surely the difficulty of providing individuals with a deep understanding of these spatial-network competition and equilibrium processes that occur in transportation.

2.2 The Socioeconomic, Technological and Institutional Environment

In order to evaluate alternative supply and operating policies through changes in networks, types of vehicles, schedules, fares, routes, maintenance, etc., transportation planners and managers must take into consideration various socioeconomic, technological and institutional factors. These include demographic trends, inflation rates, labor costs,

energy prices, interest rates, vehicle and infrastructure efficiency and prices, technological innovations, union rules, regulations, subsidy policies, etc.

In other words, considering that the performance of a transportation system is defined by the service levels, the resources consumed to provide services and the volumes moving on the network (see Manheim [17]), we are aware that all these three performance dimensions are not free from the constraints and pressure of a complex and changing environment.

A clear understanding of these relationships is a prerequisite for predicting how the combined effects of decisions and the environment actually affect the achievement of objectives such as "cost minimization", "market share maximization", or "profit maximization". For instance, a large increase in energy prices may trigger a large increase in airline fares followed by a decrease in the air industry market share and profit, while forcing a smaller fare increase in the bus industry (where energy costs remain a smaller portion of total operating costs) together with an increase in bus companies' market share and profit. Deregulation in the airline industry in the U.S.A. is another example of the importance of the institutional environment on company's productivity, competitiveness and operations. (For instance, deregulation accelerated the development of the so-called "hub-and-spoke" networks. See Morrison and Winston [20]).

2.3 The Decision-Making and Information Management Process

The complexity of analysis and decision making within any intercity passenger transportation company (as it is for many other sectors) may be characterized by (i) the multiplicity and diversity of possible decisions, (ii) the existence of various levels of decision making and various actors, with different and sometimes conflicting objectives and different planning/management horizons, (iii) the high level of interdependence and interaction between all levels, all actors and all their decisions, and (iv) as

discussed in the previous sections, the obligation to deal with a complex and changing environment.

Complexity however does not mean anarchy. In most organizations, there is usually an organized decision-making process which is supported by some other formal process for the production and exchange of information. The problem is that different people in the organization usually have a different understanding or distorted image of these processes. Thus another crucial objective of education and training in transportation is not only to make individuals aware of the above-mentioned difficulties, but to help them develop a correct conceptual model of the integrated decision-making and information management process that is necessary to overcome these difficulties.

Figure 2 schematizes such a conceptual model. Like others and the author in another paper (see for instance Assad [2] and Wong [27], and Lardinois [16]), we have identified, in its "decision-making" element, three distinct but interrelated levels that are usually explicitly or implicitly present within any transportation company: a strategic level, a tactical level, and an operational level.

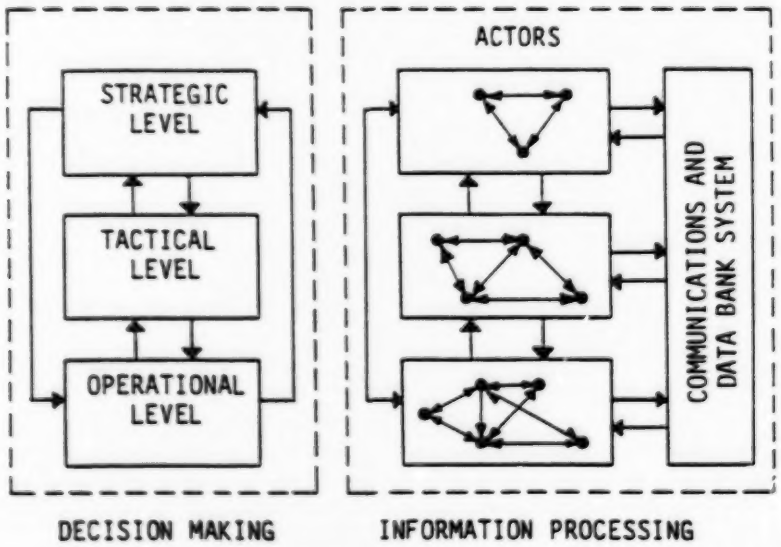

Figure 2. The decision-making and information management process

Generally speaking, at the strategic level, decision making is applied to the definition of a supply policy for the company, to resource acquisition and to major investment allocations. At this highest level, decisions have system-wide long-lasting impacts. They deal with market choices, network configurations, fleet and human resource planning, marketing strategies, terminal capacity planning and location, bank activities, budget planning, etc.

Tactical decisions, at a "lower" level, have medium-term planning horizons. They are concerned with allocating existing human and material resources of the company in order to improve its productivity and competitiveness rather than acquiring major new resources. Typical decisions at this level include frequency choices, service schedule planning, maintenance policies, etc.; they imply some trade-offs between the levels of service and costs. Fare choices may be regarded as either tactical or strategic decisions depending on their importance in marketing strategies.

Finally, at the "most disaggregated" level, i.e. the operational one, the company has to solve its short-term practical problems and organize in detail its daily and weekly activities. The detailed routing and scheduling of vehicles and crews, and real traffic control on the network are typical issues at the operational level.

The other part of Figure 2 emphasizes the fact that information flows and communication devices associated with a data bank accessible to all parts of the organization are important in order to provide all concerned actors with (i) a good knowledge of all functions performed at all levels of the company, (ii) a pragmatic consciousness that these functions involve various problems differing in scope, level of detail, time horizon and financial cost, (iii) a deep understanding that, from the lower operational level to the higher strategic level, all decisions are highly interdependent.

3. INTERCITY TRANSPORTATION MODELLING AND SIMULATION GAMING

3.1 Transportation Models and the Need for Comprehensiveness

Transportation modelling is the most well-known and sophisticated technique used to analyze transportation systems. It provides a way to deal with the combinatorial complexities and interaction effects that arise in real situations where a variety of decisions and network-wide impacts are being considered simultaneously.

In the intercity passenger transportation sector in particular, research has been primarily concentrated on the development and calibration of travel demand models to analyze and predict the demand for transportation (see for instance Stopher and Meyburg [24], Domenich and McFadden [4], Gaudry and Wills [12], and Gaudry [11]). There is still a lot of research under way in this field.

The supply side of intercity passenger transportation has also attracted and is still attracting the attention of researchers in two directions. The first one is devoted to the development of predictive supply models for the evaluation of the effects of alternative supply actions on the performance of transportation systems. A typical problem in this area is the prediction of passenger assignment on the network of flight schedules supplied by an airline company. The second direction of research deals with normative supply models for the optimization of supply actions. These models can be grouped in three categories: infrastructure or service network design models, vehicle routing and scheduling models (including vehicle fleet sizing) and manpower scheduling models, and models used in transportation control systems. For a detailed review of these predictive and normative supply models for intercity passenger transportation, see Lardinois [16].

There is no doubt that demand and supply models will continue to be of primary importance in helping transportation planners and managers in their work. Note, however, that such models with the corresponding computer software do have some limitations. First, each of these models is by nature limited to one particular issue at one particular level of the analysis and decision-making process. In general, each model is used individually by making simple assumptions about other elements of the system. For instance, demand models assume that supply and service levels are fixed; network design models assume a non-competitive environment and are not concerned with routing and scheduling matters at the operational level; crew scheduling models assume that vehicle schedules are fixed, etc. Secondly, these models focus on strictly technical transportation problems, with little or no consideration to other related business matters such as organizational structure, budget planning, marketing, and to "external" issues such as government regulations or subsidy policies. Thirdly, they do not include a human element in the simulation of the supply side of the system under consideration, simply because it proved to be difficult to model the individual's decision-making process. Unfortunately, such models lack the human-related uncertainty dimension of real-life transportation situations.

To summarize, it remains true that intercity passenger transportation planners and managers possess no tools – except their own experience – to grasp the multiple and interacting dimensions of the decision-making process and the whole transportation environment. The need for such comprehensive tools is seen in at least three contexts: (i) in situations where decision-makers are considering large modifications in the strategies, tactics and operations of their company, (ii) in situations where

they are considering different scenarios with regard to the evolution of the environment, including the behavior of other transportation modes and companies, (iii) in transportation education and training. In the first two cases, decision-makers would appreciate having some tool which could be at least be used as a laboratory for discussing and experimenting the ideas or scenarios under consideration. In the third case, there is a need for providing individuals with a deep, "systemic" understanding of complex transportation situations and excellent management skills.

To meet this need for comprehensive analysis, experimentation and training tools, the integration of transportation models such as those discussed previously with the so-called "gaming approach" developed in several fields as a surrogate for the unmodelable human decision-making element, is a solution technique discussed hereafter.

3.2 Simulation Games in General and in the Transportation Industry

Whether computer-based or not, simulation games that replicate complex systems involving human behavior or decision making have a long history in business and management. This is also the case in many other fields as diverse as political science, psychology, communication and information technology, language acquisition, urban and regional planning, transportation, health care systems, national energy planning, and military science which is considered to be the first area where organized games originated.

Simulation games can be classified in different ways. One commonly accepted typology deals with "systemic" games vs. "role-playing" games (Rice et al. [22]). Systemic games focus on interrelationships and interdependencies among elements of an economic, political or social system where players develop their own role behaviors. Role-playing games focus on

given particular positions in the real world and relationships among these positions; for example, they deal with negotiations and compromises between urban politicians, planning administrators and real-estate speculators. Two other typologies are particularly relevant to business games. The first one makes a distinction between "general" games and games specific to a particular industry. The second one makes a distinction between "total entreprise" games covering a wide range of managerial disciplines (production, marketing, etc.) and functional games emphasizing one specific discipline (see Fritzche [10]). For a discussion of main theoretical concepts and techniques of simulation gaming (mainly in social sciences), see Greenblat and Duke [15] and Greenblat [14]. For a brief history and synthetic review, see Rice et al. [22, pp. 3-13] and Elias [6, pp. 17-25]. A detailed review and discussion of business games in particular can be seen in a special issue of the **Simulation and Games** journal [23].

Like Willumsen and Ortuzar [26], we view gaming simulation as a sequential decision-making exercise whose basic function is to provide an artificial environment where some characteristics of a real situation are replicated, enabling players to follow up the consequences of their decisions with rapid response. Its objective is to enhance a comprehensive understanding of complex systems and to develop learning skills.

Given the possibility of using mathematical techniques to model some aspects of transportation systems, the above definition naturally leads to the idea mentioned previously, i.e. the embedding of transportation models in larger simulation gaming exercises replicating complex real-life transportation situations. This idea is not new. However, it has been studied by a relatively small number of researchers and applied to transportation situations that are different from the "competitive multimodal multicompany intercity passenger transportation network" situations discussed in this paper.

Actually, there is a whole family of games concerning land use, urban development and other related matters such as urban transportation (see Greenblat and Duke [15], Environmetrics [7], Rice et al. [22], and Coppard and Goodman [3]). However, only some of them are computer-based and deal explicitly with transportation issues, among other urban matters. As for games concerned mainly with urban transportation, there are, to our knowledge, only three that are documented (see Willumsen and Ortuzar [26], Rice et al. [22], and Adiv [1]).

In the field of intercity passenger transportation, we are aware of the existence of six games. Among these, there are only two that consider more than one mode of transportation. The first one (Ortuzar and Willumsen [21]) is built around a simplified model of the ground transportation system of a relatively isolated developing country. Players represent three key institutions: the ministry of transport, the nationalized rail industry, and the independent coach industry; in each industry, there is just one decision-maker who has monopoly of all corresponding services. The second multimodal game (Mokhtar [18]) deals with the planning process of the road, rail and air transportation system in a hypothetical regional corridor made up of different aligned districts. The four other games are specific to the air transportation industry. Three of them are typical marketing-oriented games which have been developed by Air Canada, the University of Tennessee (see Graham and Gray [13]) and the McDonnel Douglas Corporation (see Tyber [25]). The fourth airline game, which models different stages in the overall planning/management process, has been developed by Elias [6] on the mainframe of the Flight Transportation Laboratory at M.I.T.

To conclude this short overview of intercity passenger transportation models and games, it is worth mentioning that we have not yet identified any research activity towards the development of a true multimodal

multicompany simulation with supply-demand network equilibrium that would take into consideration the competition between different companies and modes, and the fact that some travellers may actually use different successive companies and modes from their origin to their destination (Lardinois [16]).

4. JET-SET: A COMPETITIVE MULTIMODAL MULTICOMPANY INTERCITY PASSENGER TRANSPORTATION GAME

All previous comments converge to the realization of the need for simulation tools dealing both with the modelling of multimodal multicompany intercity passenger transportation networks and the multidisciplinary management of companies competing on these networks. Combined with the realization of the many advantages provided by micro-computers, this observation was at the origin of JET-SET, a simulation and management game designed as an analysis, experimentation and training tool in the field of intercity passenger transportation, for use on IBM-PCs. (Its name is a bilingual acronym for Jeu Educatif en Transport/Simulation for Education in Transportation).

The first version of JET-SET was completed in 1985 under contract with the George A. Scott Centre, which is the Training Institute of the Canadian Ministry of Transportation. This section deals with the second, improved version.

4.1 Design Objectives and Main Features

The goal of JET-SET is to create an artificial environment with the following main objectives and features:

a) The simulation should reproduce, to a great extent, the complexity of real-life situations typical to the intercity passenger transportation industry, making clear that this complexity stands at two levels: the "company" (decision-making) level and at the "external" or "environmental" level.

b) At the company level, the game should illustrate the multidisciplinary and systemic nature of the decision-making process, thus enabling players to actually make diverse, interrelated decisions as those encountered in practice. It should also enable participants to follow up the consequences of their decisions and make them aware of the existence of alternative and perhaps conflicting objectives.

c) At the external level, the simulation should provide participants with a comprehensive understanding of the spatial network competition and interaction between different modes and companies, of the travellers' behaviour on the network, and of the mechanisms that determine the resulting equilibrium between supply and demand. The game should also enable each participant to understand the effect of the socioeconomic, technological and institutional environment. In particular, it should allow for the consideration of different policies and conditions concerning regulation or deregulation of the transportation industry.

d) The software must be easy and friendly to use. It must also be realistic with regard to the similarities between the information provided to players and the information available in real companies.

Simplifications made in relation to real-life situations concern mainly the detailed management of company operations: decisions at the operational level, such as vehicle routing and scheduling matters, are not considered in the current version of the game.

4.2 Competition in JET-SET

In a typical JET-SET game, players are divided into competing groups, each group being in charge of one company. The game master, who is responsible for the "orchestration" of the simulation, has a choice between two such competitive situations. In the first one, there are six companies (six players or teams of players) serving a set of large and small cities with populations and relative locations representative of a typical

European geographic area such as France, or a North American region such as the Toronto-Montreal-New York area. The road and rail infrastructure is illustrated in Figure 3. The six companies are: one conventional rail company, one rapid train company, two traditional bus companies, and two airlines, one of which offers STOL (short take-off and landing) services. The automobile mode is also modelled, but there is no player to represent it; the modification of its relative attractiveness depends only on energy prices. The second competitive situation emphasizes the competition within one particular mode. There are four players in charge of four different bus companies; the other rail and air modes are also present, but the corresponding services are fixed.

Competition with JET-SET may be induced in a completely different way, i.e. by making all players in charge of the same company in the same initial conditions, and comparing their performances with regard to the evolution of their company. More precisely, the third situation "available" to the game master is a situation where all players are in charge of the same bus company and operate "in parallel", while services supplied by the other rail, air and bus companies are fixed.

Sections 4.3 and 4.4 deal mainly with the first two game situations where there is a direct competition between players on the network.

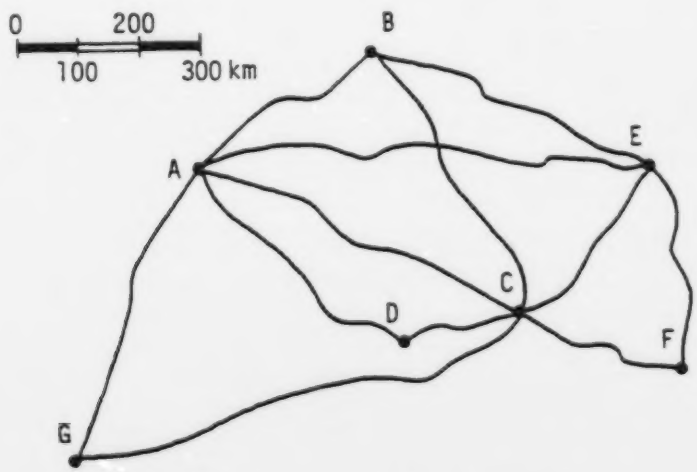

Figure 3. Road and rail infrastructure in JET-SET

4.3 Running of the Game and Supply-Demand Simulation

Participants play the role of planners/managers responsible for all activities of their respective company. They may pursue different objectives or combinations of objectives (market shares maximization, cost minimization, etc.), which may actually vary from one part of the service network to the other depending on local conditions. Experience with JET-SET has also proved that, during the game, players learn from the output of the simulation to adjust their initial objectives. As for the game master, he represents a "superior authority" invested with the power to influence and control some aspects of the socioeconomic and institutional environment.

Each run of the game represents one year of operation of all companies. At the beginning of each run, each player is required to make several decisions concerning his company. To do so, he uses the information contained in an activity report that he has received at the end of the previous year. The game master also receives a year-end report in order to prepare his own decisions. Once the players and the game master have made their decisions, they are entered into the computer program which then simulates their consequences. New reports are then handed out to the players and the game master, and the process begins again. In what follows, we describe more precisely the running of the game and the transportation demand-supply simulation performed at each run.

At the beginning of a "match", each company is in a predetermined situation: it owns a fleet of vehicles with given technoeconomic characteristics (price, capacity, operating costs, life span, etc.), it serves different pairs of cities in given transportation times with given daily frequencies and fares, and it seizes certain market shares, etc. Depending on the vehicle fleet size and the work load on the service network, some vehicles may not be used. Each company is also in a predetermined state with regard to its financial situation.

Decisions open to each player at the beginning of each year are as follows.

(a) *Choice of markets and transportation services.*

These decisions concern the fares and daily frequencies for all city pairs to be served by the company. In a completely deregulated environment (this depends on the game master), each company may enter or leave any market at any time; the configuration of the service network of each company may change completely from one year to the next. The only restriction, for bus and rail companies, is to deal with the fixed road and rail infrastructure. In a regulated situation, such a total freedom is not provided. If a company serves a city pair at the beginning of a match, it must maintain a minimum level of service during all successive runs. On the other hand, if it does not provide any service between two cities at the starting year, it will not be allowed to enter this market. Furthermore, the variations in fares and frequencies on city pairs initially served are constrained by limits imposed by the game master.

(b) *Additional passenger services.*

These services deal, for instance, with luggage services at terminals, reservation facilities, in-vehicle passenger amenities (meals, drinks, music, etc.) and other services which are currently supplied by transportation companies for attracting customers. Each player has the possibility of choosing between three different levels of such services with three different costs.

(c) *Vehicle fleet.*

Depending on the size and age of his vehicle fleet, a player may decide to purchase or lease vehicles in order to expand his transportation services or balance the shelving of vehicles that reach the retiring age.

(d) *Financial activities.*

Depending on the financial situation of his company and all expected costs and revenues for the next year, a player may decide to borrow

money from financial institutions at a given loan rate or repay a part of his debt, if any. There is a limit as to the amount of money that can be borrowed. Funds remaining at the bank will produce an interest below the loan rate.

(e) *Marketing.*

In order to improve the attractiveness of his company, each player may initiate a promotional campaign for which he will pay in proportion to his revenues.

(f) *Special market studies and "self" analysis.*

In order to increase the amount and level of detail of the information that he will receive at the year end, a player may initiate special studies such as an origin-destination survey, a detailed study of the structure of supply and demand in all markets, or an analysis of the operations of his own company. Of course, he will have to pay for all of this.

As indicated previously, the beginning of each year provides the game master also with the opportunity to make decisions relevant to his role in the simulation. These decisions deal with the population growth rate and the linguistic composition of each city (in bilingual countries such as Canada, the second factor influences the level of transportation demand between cities), energy prices, labor unit costs, interest and loan rates, government subsidy policies, the income tax rate, and regulations as explained earlier.

Besides the players and the game master, there is a third category of actors within the game. They are the travellers themselves who are internally modelled and not represented by any participants. Travellers' behavior on the network, for each city pair, depends both on the attractiveness and the availability of all alternative routes, including direct services, if any, and as routes made of successive services corresponding to possibly different modes or companies with connections at intermediate cities. The attractiveness or utility of each route is computed from the

characteristics of the services making the route: the basic desirability of each corresponding company, fares, frequencies, and transportation times. A route's attractiveness also takes into account the connecting times/costs if any, and egress times/costs to reach the service network at the origin and exit at the destination. As for the availability of a route, it takes account of capacity limitations.

The total transportation demand between two cities depends on the global (aggregated) attractiveness of all routes between them, on the given economic interdependence characterizing their historical interrelationship, and on the above-mentioned demographic factors. This total demand is modelled as a daily demand, with all days of the year being identical. Thus, there is no seasonal, monthly, weekly, or daily variation of the transportation demand in JET-SET.

Consistent with the objective of realism, the transportation demand takes account of two categories of travellers: business and non-business. These two categories have different attitudes with regard to trip times, fares and frequencies, and consequently they behave differently on the network. The proportion of each category is different for each city pair. Furthermore, it may change with time since the variation in the attractiveness of transportation services affects each category differently.

The computer program into which the decisions of the players and the game master are entered, creates the evolving environment where all companies and travellers are simultaneously present. The program simulates the interacting effects of these decisions on the multimodal multicompany transportation network, on the socioeconomic and institutional environment and on the resulting behavior of travellers. Moreover, it simulates all the operations of each company and gives an account of the multifunctional management within each one up to the updating of its financial situation. After execution of the program, the companies face a new situation that corresponds to the state of the system one year later, with a new equilibrium between transportation supply and demand. New reports are then

produced which describe this new situation and all the activities that took place during the year.

A complete game covers a series of simulated years in such a way that the evolution of each company depends not only on the decisions made by its manager, but also on those made by other companies and the game master. Thus JET-SET can be described as a dynamic simulation and sequential decision-making exercise which truly models: (i) the behavior of both the supply and demand sides of multimodal and multicompany intercity passenger transportation networks, and (ii) the "business/management" activities performed in each company.

The training capability of the game rests on the progressive learning that is achieved through the sequential analysis and decision-making process in which each player is involved. In this respect, the output from the simulation plays a crucial role. The information provided in each player's report at each year-end contains three groups of data. The first one is general data giving an overview of both the transportation system as a whole, and the socioeconomic and institutional environment. The second group of information is partially private data that concerns the player's company. This information describes its vehicle fleet and its physical operations on the network; it provides operating statistics concerning ridership, vehicle-kilometres/year, vehicle occupancy, etc; it also gives in-depth financial data and statistics. All this information is presented in various tables similar to those available in real companies. For instance, it contains a standard financial review that includes all categories of operating and non-operating revenues and expenses concerning ticket sales, salaries, energy costs, administration, passenger amenities, amortization, vehicle renting, interest income, loan interest, income taxes, government subsidies, etc. The data also provides a statement of changes in the financial position of the company, together with various

statistics describing the company's productivity. The third group of information is special data provided to each player who has requested special studies in order to know more about the travellers' behavior and the activities of all companies on the various markets and segments of the transportation network.

As for the game master's report at each year-end, it includes the above-mentioned general data common to all companies and most of the two other types of data concerning all of them. Upon request, the report may also include a synthesis review that describes, year after year, the evolution of (i) each company's operations and financial situation, and (ii) the level of service supplied to travellers in each market by all companies taken as a whole. Such a synthesis review is useful in mid-game discussions with players and in the final debriefing session.

4.4 Structure of the Software and the Simulation Program

The software is composed of three parts: (i) a data bank containing all the information that describes the successive states of the transportation system, the companies and their environment; (ii) an interface between the user and the data bank, i.e. a user-friendly program for an easy collection and validation of the players' and the game master's decisions, as well as for the editing of the output reports; and (iii) a simulation program which models all the relationships between all the system's variables and determines the effects of the decisions made by the players and the game master.

The structure of the simulation program is schematized in Figure 4. It includes four major components. In short, the operation model – the simplest of all four – makes an account of the physical operations of each

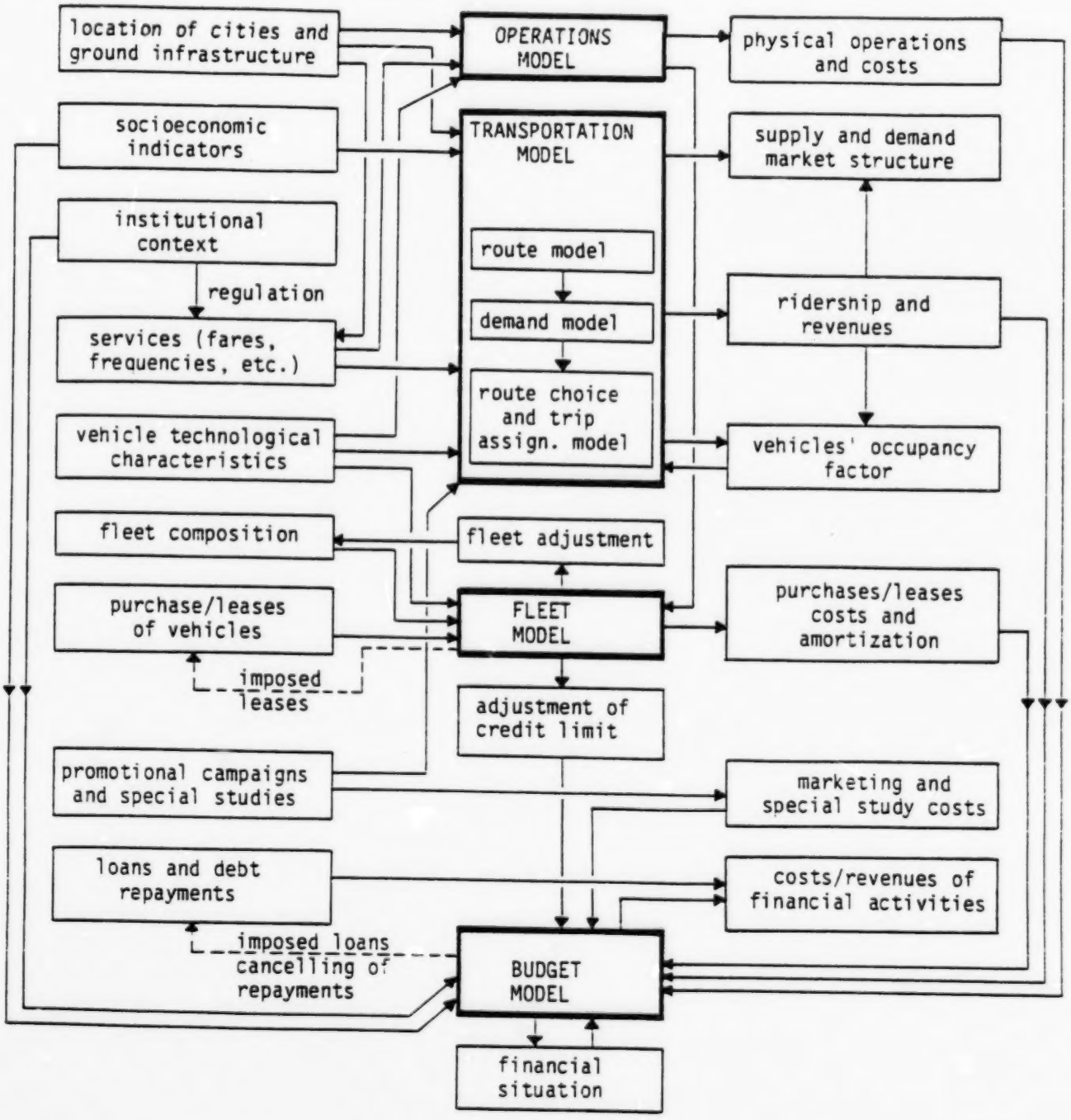

Figure 4. Structure of the simulation program

company on all segments of the service network and evaluates their costs. The inputs for this computation are the supplied services and the operating unit costs, the latter being a function of possible variations in energy and manpower unit costs. Services decided by players may be automatically adjusted in order to take account of regulation constraints.

The vehicle fleet model has four major functions applied to each company. The first function is to proceed to the annual adjustment of the vehicle fleet (aging of vehicles, shelving of vehicles that are too old, and the introduction of newly purchased or rented vehicles). The second function is to check the compatibility between the fleet size and the vehicles' work load. In the case of non-compatibility, the program automatically applies "imposed leases", forcing the company to lease additional vehicles with a financial penalty. The third function is to update the credit limit on the assumption that banks determine this limit according to the residual value of the fleet. The fourth function is the registering of the costs of all purchases and leases of vehicles, as well as the amortization costs that are calculated over the vehicles' life span.

The transportation model is the central element of the simulation program. To our knowledge (see the end of section 3), it is also the only model which truly deals with competitive multimodal multicompany intercity passenger transportation networks. It is based on the assumptions presented in section 4.3 which concern the behavior of travellers facing alternative multimodal and multicompany routes to go from their origin to their destination. This transportation model is composed of three submodels. The first is a route model which identifies all possible alternative routes for each city pair and determines their respective attractiveness. The second one is a demand model that determines the level of the transportation demand between each city pair for each category of travellers (business and non-business), taking into consideration the fact that these two categories

do not react in the same way to the supplied services. The third submodel is a route choice and trip assignment model that simulates the behavior of both categories of travellers on the network. It includes an iterative procedure that takes into account the availability constraints imposed by the offered capacities. The route choice and trip assignment is cyclicly repeated until all travellers are assigned a way to go from their origin to their destination (including by car).

The budget model simulates the financial activities of each company at the beginning and the end of each year. At the beginning, the program verifies if the companies are capable of doing the proposed operations such as vehicle purchases or leases, loans and debt repayments. Otherwise, the program imposes additional loans (with a rate higher than the regular loan rate) and/or postpones repayments. The program is then used at the year end in order to take account of all other costs and revenues, which may force again some companies to cancel some debt repayments or make an imposed loan.

5. EXPERIMENTATION AND CONCLUSION

A preliminary version of the game was run experimentally in 1984 at the George A. Scott Centre (Cornwall, Ontario) of the Canadian Ministry of Transportation. This first trial was excellent, although the program presented various weaknesses at that time. The final first version, JET-SET/1, was completed in 1985 and tested again with great success at the George A. Scott Centre, and by the staff of the Transportation Development Centre (Montreal) of the same Ministry. It was also experimented at the Canadian Marine Transportation Centre of Dalhousie University – which is now the International Institute for Transportation and Ocean Policy Studies (IITOPS) – and during a seminar organized by the author at the Université de Montréal. All transportation professionals and students that

participated in these experiments were in general very satisfied with the technical and didactic capabilities of the system. We thus decided to make it publicly available.

Until now, JET-SET/1 has been distributed to about twenty universities and governmental organisms in Canada, U.S.A. and France, as well as to the VIA Rail Canada Inc. transportation company. At the George A. Scott Centre, JET-SET/1 has been used 6 times in a senior transportation management course for top and intermediate managers and officers from both private and public organisms; about 250 participants have been involved in these 6 sessions, and the reaction has been "positive for 95% of them" (quoted from a letter). At IITOPS, it has been used at least three times during 1986-87 in a second year MBA transportation management course with "considerable success" (quoted). At VIA Rail, at least three sessions have been completed in 1986, for a total of 36 participants; their comments were again positive: "Gives insight into the global process of decision making (...) Gives one a better understanding of the constraints and advantages of each mode of transportation (...) Appreciation of other department roles (...) Better appreciate the economic factors involved (...) New outlook on what is required to manage a transportation company (...) Helps us to learn strategies". A new employee added: "All new employees should begin their work at VIA by taking the program. Great way to learn the business and also facilitates the integration of new employees". Some other users indicated that the game did not meet their own needs, but in general the reaction was excellent and different users indicated a desire to become aware of further developments.

Comments such as these gave us an incentive to proceed with the elaboration of a second version, JET-SET/2, which integrates most features of the first version while taking into consideration the various suggestions obtained from first users. What has been presented in the previous pages deals with this second, improved version.

We are now working on a third version, JET-SET/3. The idea is that JET-SET/2 takes into account most of the dimensions, complexities and levels of decision making discussed in section 2, except for the one defined as the operational level. Thus, we are trying to include routing and scheduling matters so that players can make up daily service schedules, while taking into consideration the variations in the transportation demand with the time of day. This will force each player to design "simultaneously" both the timetable and the vehicle routes and schedules. To do so, he will use an interactive-graphic program which is currently under development.

To conclude, it is worthwhile emphasizing that, now more than ever, intercity passenger transportation planners and managers do not have any choice but to enhance the competitiveness and productivity of their company while supplying better and often more services to travellers. In such a context, there is a need for providing them – and students interested in the field – with a deep understanding of transportation systems and excellent management skills. This also partly applies to a governmental context where there is a requirement for a good knowledge of the transportation industry in order to generate adequate policies. Furthermore, there is a need for ways of experimenting alternative strategies or operating plans without being forced to test them in the "real world". The use of comprehensive simulation and management games which, like JET-SET, are designed as analysis, experimentation and training tools, is one way for meeting these needs.

REFERENCES

1. Adiv A (1986) A game/simulation for transportation management. *J. Transpn. Engng.* **112**(1), 88-104.
2. Assad AA (1980) Modelling of rail networks: towards a routing/makeup model. *Transpn. Res.* **14B**, 101-114.
3. Coppard LC and Goodman FL (1977) Urban gaming simulation '77. School of Education, Univ. of Michigan.
4. Domencich TA and McFadden D (1975) *Urban Travel Demand.* North Holland, Amsterdam.
5. Eilon S (1986) Education and training in management schools. *Omega* **14**(3), 195-201.
6. Elias AL (1979) The development of an operational game for the U.S. domestic airline industry. FTL Report R78-5, MIT Flight Transportation Laboratory.
7. Environmetrics, Inc. (1971) The state-of-the-art in urban gaming models. Report for the U.S. Dep. of Transpn., Springfield, VA.
8. Florian M and Gaudry M (1980) A conceptual framework for the supply side in transportation systems. *Transpn. Res.* **14B**, 1-8.
9. Florian M, Gaudry M and Lardinois C (1988) A two-dimensional framework for the understanding of transportation planning models. Forthcoming in *Transpn. Res.-B.*
10. Fritzsche DJ (1987) The impact of microcomputers on business educational simulations. *Simulation and Games* **18**(2), 176-191.
11. Gaudry MJI (1984) Functional form and stochastic specifications: current applications to aggregate time-series and cross-sectional travel demand. In *Transportation Planning Models* (edited by Florian M), North Holland, Amsterdam.
12. Gaudry MJI and Wills MJ (1978) Estimating the functional form of travel demand models. *Transpn. Res.* **12**, 257-289.
13. Graham RG and Gray CF (1969) *Business Games Handbook.* American Mgmt Ass., New York.
14. Greenblat C (1987) *Designing Games and Simulations.* Sage Publ., Newbury Park, CA.
15. Greenblat C and Duke R (1975) *Gaming-Simulation: Rationale, Design and Applications.* John Wiley, New York.
16. Lardinois C (1987) Supply models for intercity passenger transport: a review. *Transp. Reviews* **7**(2), 119-143.
17. Manheim ML (1980) Understanding "supply" in transportation systems. *Transpn. Res.* **14A**, 119-135.
18. Mokhtar H (undated) Multi-modal intercity demand analysis and supply simulation teaching model. Dep. of Civil Engng., Univ. of Toronto.
19. Morlok EK (1979) *Introduction to Transportation Engineering and Planning*, Chap. 2, McGraw-Hill, New York.
20. Morrison S and Winston C (1986) *The Economic Effects of Airline Deregulation.* The Brookings Institution, Washington, D.C.
21. Ortuzar JD and Willumsen LG (1978) Learning to manage transport systems. *Traffic Engng. Control* **19**(5), 236-239.
22. Rice RG, Found WC and Gribble SF (1974) An interactive transportation gaming model for metropolitan Toronto: progress report. Research report 17, Univ. of Toronto - York Univ. Joint Program in Transpn., Canada.

23. *Simulation and Games*, Special Issue: A Practical Guide to Business Gaming (1987) **18**(2).
24. Stopher PR and Meyburg AH (1976) *Behavioral Travel-Demand Models*. Lexington Books, Mass.
25. Tyber HB (1977) An airline management game. Douglas Paper 6671, McDonnel Douglas Corp.
26. Willumsen LG and Ortuzar JD (1985) Intuition and models in transport management. *Transpn. Res.* **19A**(1), 51-57.
27. Wong RT (1984) Introduction and recent advances in network design: models and algorithms. In *Transportation Planning Models* (edited by Florian M), North Holland, Amsterdam.